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AN ANALYTICAL STUDY OF CONTACT STRESS AND CONTACT ZONE ANALYSIS OF CYLINDRICAL (ROLLER) & SPHERICAL (BALL) BEARINGS IN EPICYCLOID CONDITION

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ABSTRACT

This paper reports Contact Stress and Contact Zone Analysis of cylindrical (Roller) & Spherical (Ball) Bearings using M. F. Spotts Analytical Equation for epicycloid condition. The different combinations of ratios of its outer radius and inner radiusi.e. (R_2, R_1) and the elasticity of the material E_1, E_2 have been considered to investigate the compressive stresses (P_0), and the contact zone (a) on the surfaces of the ball & Roller bearing i.e. Analytical method is applied for the analysis of both spherical and cylindrical type of Ball Bearing Cavity. The results are compared between both type of bearings and final interpretation has been made.

KEYWORDS: Contact Stress, Contact Zone, Analytical Method & Ball Bearing

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Original Article

1. INTRODUCTION

A bearing is a supporting member between two machine parts when there is a relative motion between them. Ball and roller bearings which are commonly known as antifriction bearings have a major role in reducing the friction between machine elements when there is a relative motion between them. At initial conditions and at moderate speeds ball and roller bearings have a very low value of friction however at high speed, they are less effective than a properly designed journal bearing. Therefore, cylindrical (roller) bearing are basically employed for high speed since they provide a kinematic line contact as compared to spherical (ball) bearing which will make point contact. All these varieties of bearings have been brought to their present state of perfection only by many years of research and experimentation. Standardization of many different type and sizes of bearings has been most helpful to the designer.

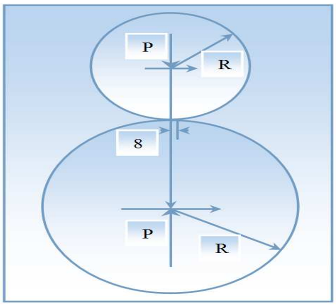

Figure1: Schematic Diagram for the Cylindrical (Roller) and Spherical (Ball) Bearing in a Dynamic Condition

In this context, one has to understand that the material near the contact zone in actual operation is under very high stress, but the stress rapidly diminishes for points at some distance away as the ball or the roller changes its point of contact. While the surrounding material at low stress is effective in preventing lateral expansion of the highly stressed material, the highly stressed material is thus in the state of plain strain. The ball bearing geometry consists of axial force (P_1), inner radius (R_1), outer radius (R_2), contact zone of the two balls (a) which can be seen in figure 1 below:

2. LITERATURE REVIEW

Many researchers have carried out the Contact stress & contact Zone analysis, of the ball and roller bearings. M. F. Spotts[1] has framed the equation of contact stress and contact zone experimentally for cylindrical (roller) and spherical (ball) bearings in dynamic conditions. G. T. Hahn[2] has used the Hertzian equation for the calculation of residual stresses and plastic deformation using torsion test carried out by Finite element method. C. T. Walters[3] has tried to study the dynamics involved by using Runga Kutta Method for four and six degrees of freedom. T. E. Tallion[4] has evaluated the various modes of failure according to the contact stress situation and has given guidelines to prevent them. R. Pandiyarajana[5] has tried to find out contact stress distribution of a large ball bearing using Hertzian elliptical contact theory.

3. PROBLEM, SCOPE & METHODOLOGY

All through the 2-D geometry of spherical (ball) bearing and cylindrical (roller) bearing appears to be same there is a wide variation in the amount of maximum compressive stress and contact zone when the axial force is applied to both this structures in a dynamic condition. When two spheres (ball bearing) are in contact, they form a point contact and when two cylindrical (roller bearings) are in contact, they form line contact.

By keeping the outer radius (R_2) constant and varying the axial load (P_1) and inner radius (R_1), the maximum compressive stress and contact zone have been calculated analytically from the dynamic equation derived by M. F. Spotts experimentally for the cylindrical and spherical ball bearings. It was found that the rotating bearings undergo a fatigue failure rather than failing due to compressive stress in the balls or races. This phenomena is quite complex and involves the various stress cycles which depend on the number of balls or roller in the bearing. The above-stated factors give an inquisitiveness to undergo a comparative study of ball and roller bearing using the analytical equations given by M. F. Spotts. The scope and methodology for the present work are as follows:

In the Present research work, an approach for the analysis of the ball and roller bearing has been carried out under axial compressive load (maximum axial load of 1000 N has been considered for analysis) and gradually it has been reduced to study the effects.

The outer radius has been kept constant $R_2 = 30$mm the inner radius R_1 have been varied as 8, 10, 12, 14, 16, 18, 20 mm respectively The values for outer compressive stress for both the spherical and cylindrical ball bearings have been compared using 2D graph and results have been analyzed. The analytical equation for Cylindrical (Roller) and Spherical (ball) bearing given by M. F. Spotts are as follows:

$$P_0 = 0.616\sqrt[3]{\left(P\left(\frac{1}{R_1}+\frac{1}{R_2}\right)^2\left(\frac{E_1E_2}{E_1+E_2}\right)^2\right)} \tag{1}$$

Equation (1), Equation for Spherical Contact Stress

$$a = 0.880\sqrt[3]{\left(P_1\left(\frac{1}{E_1}+\frac{1}{E_2}\right)\left(\frac{R_1R_2}{R_1+R_2}\right)\right)} \quad (2)$$

Equation (2), Equation for Spherical Contact Zone

$$P_0 = 0.591\sqrt{\left(P_1\left(\frac{1}{R_1}+\frac{1}{R_2}\right)\left(\frac{E_1E_2}{E_1+E_2}\right)\right)} \quad (3)$$

Equation (3), Equation for Cylindrical Contact Stress

$$a = 1.076\sqrt{\left(P_1\left(\frac{1}{E_1}+\frac{1}{E_2}\right)\left(\frac{R_1R_2}{R_1+R_2}\right)\right)} \quad (4)$$

Equation (4), Equation for Cylindrical Contact Zone

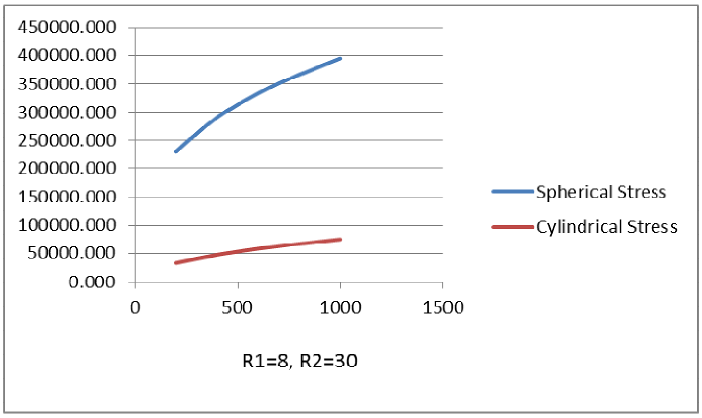

Figure 2: Graph Between Spherical & Cylindrical Stresses at R_1=08 & R_2=30

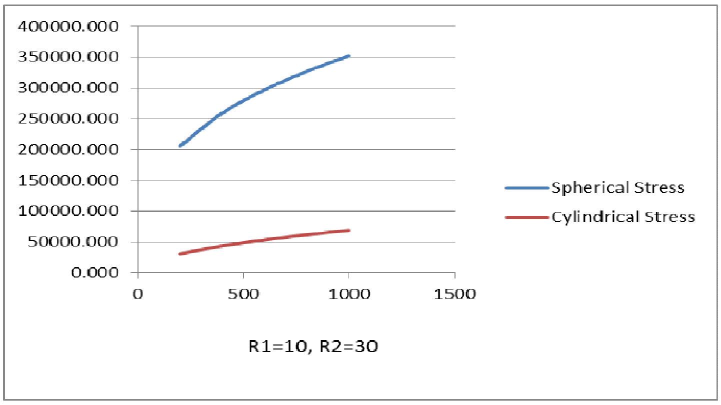

Figure 3: Graph between Spherical & Cylindrical Stresses at R_1=10 & R_2=30

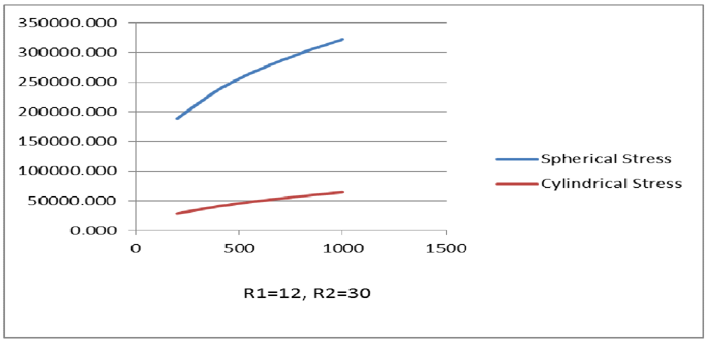

Figure 4: Graph between Spherical & Cylindrical Stresses at R_1=12 & R_2=30

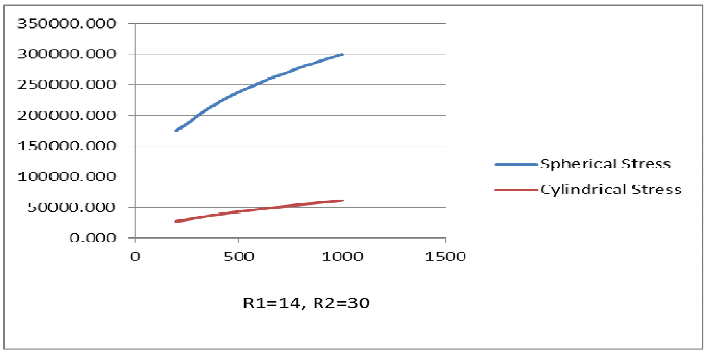

Figure 5: Graph between Spherical & Cylindrical Stresses at R_1=14 & R_2=30

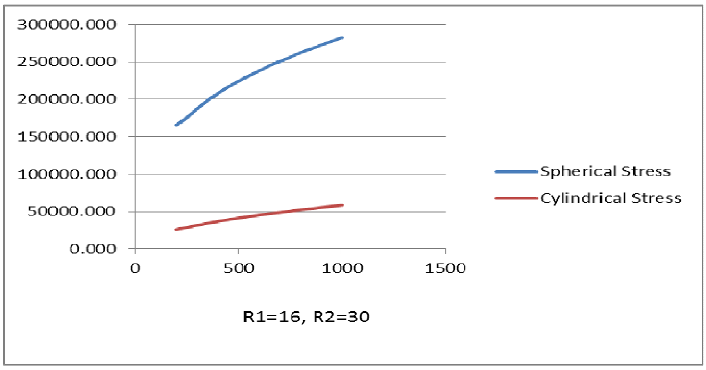

Figure 6: Graph between Spherical & Cylindrical Stresses at R_1=16 & R_2=30

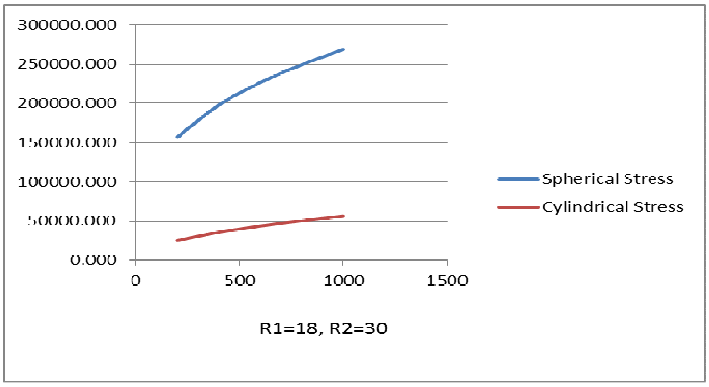

Figure 7: Graph between Spherical & Cylindrical Stresses at R_1=18 & R_2=30

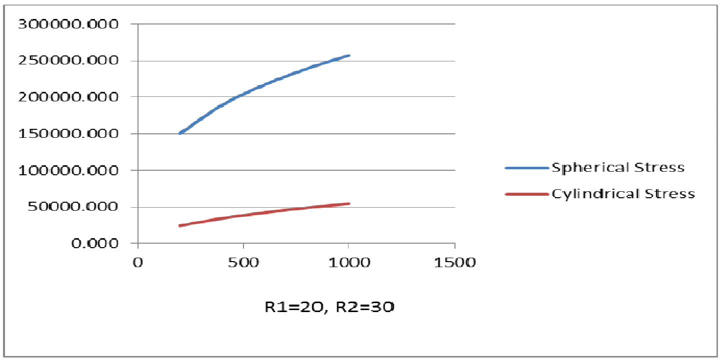

Figure 8: Graph between Spherical & Cylindrical Stresses at R_1=20 & R_2=30

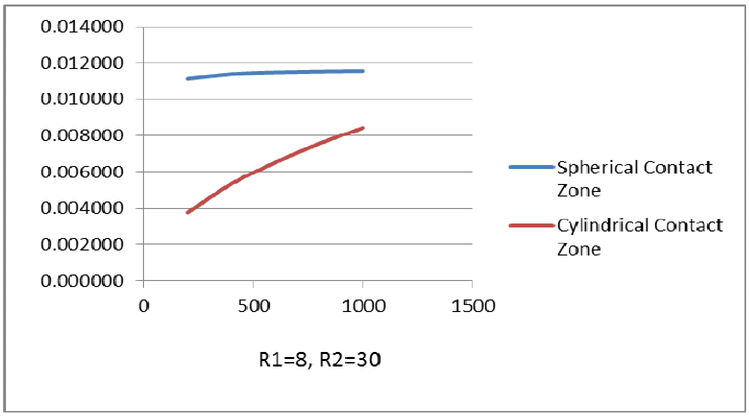

Figure 9: Graph between Spherical & Cylindrical Contact Zone at R_1=08 & R_2=30

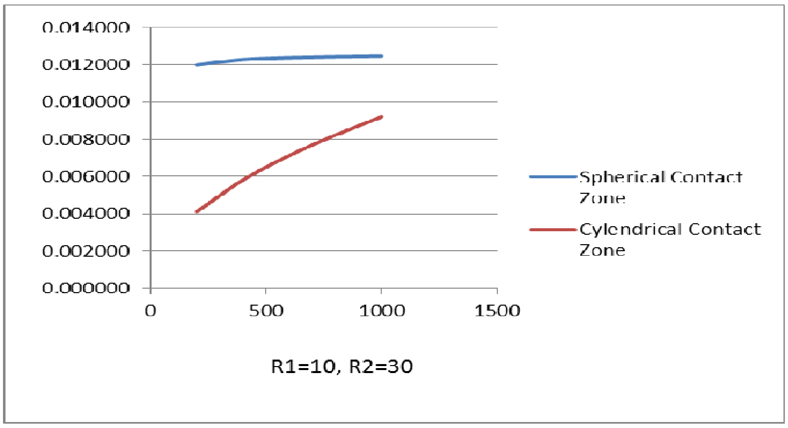

Figure 10: Graph between Spherical & Cylindrical Contact Zone at R_1=10 & R_2=30

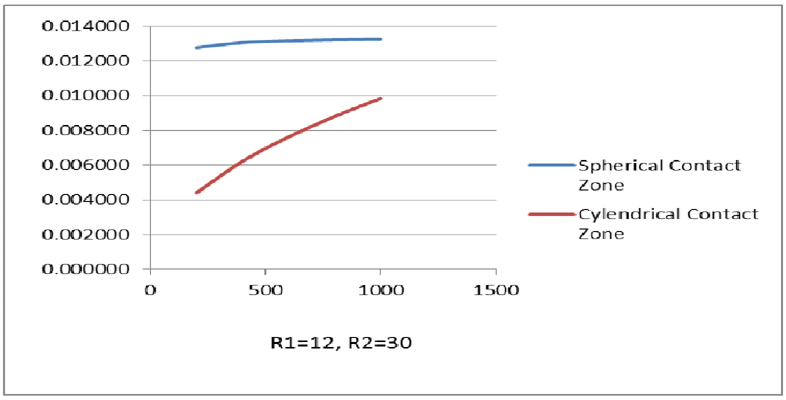

Figure 11: Graph between Spherical & Cylindrical Contact Zone at R_1=12 & R_2=30

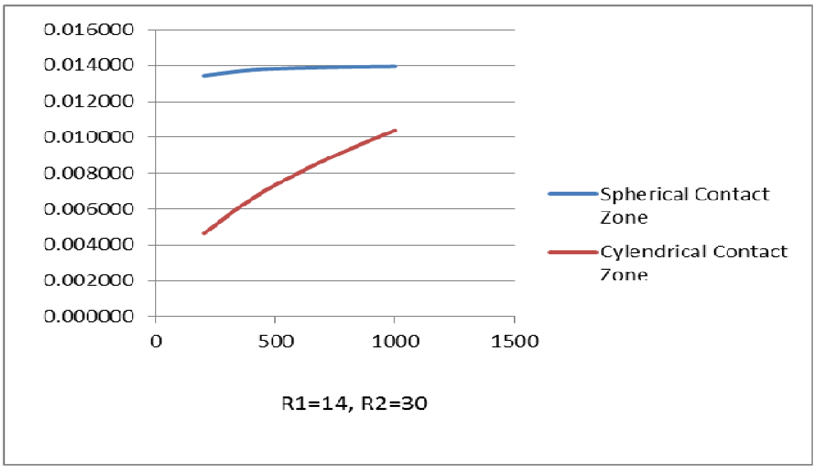

Figure 12: Graph between Spherical & Cylindrical Contact Zone at R_1=14 & R_2=30

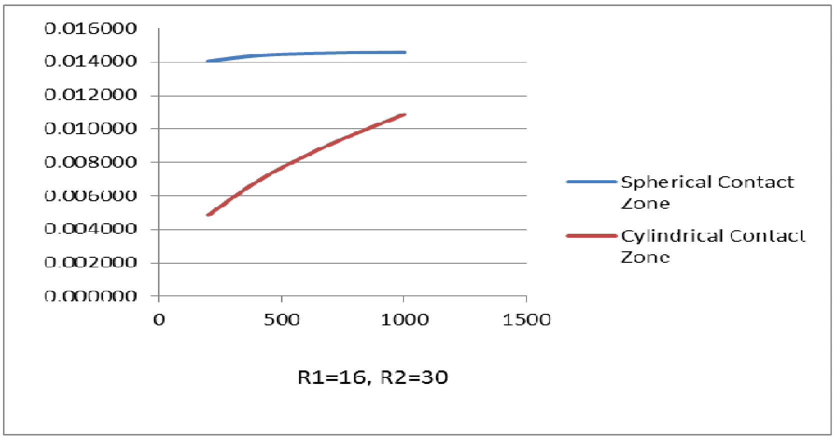

Figure 13: Graph between Spherical & Cylindrical Contact Zone at R_1=16 & R_2=30

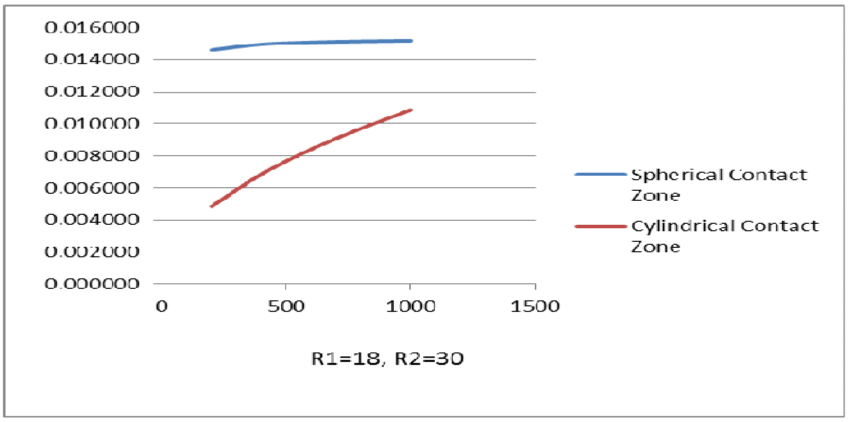

Figure 14: Graph between Spherical & Cylindrical Contact Zone at R_1=18 & R_2=30

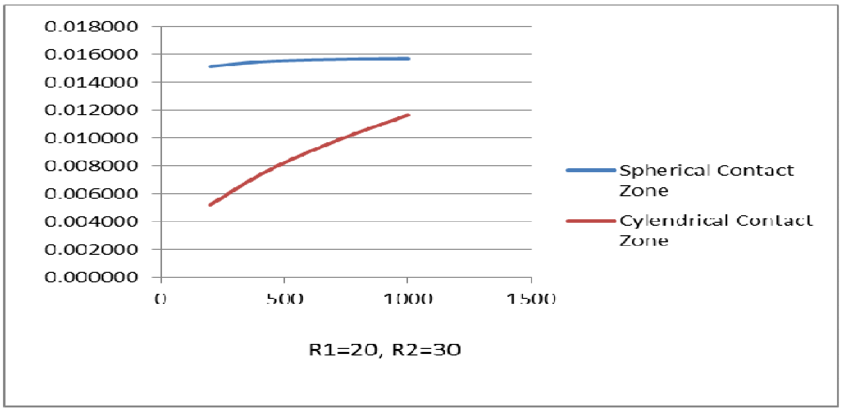

Figure 15: Graph between Spherical & Cylindrical Contact Zone at R_1=20 & R_2=30

4. RESULTS AND DISCUSSIONS

- It is observed from Fig. 2, 3, 4, 5, 6, 7 & 8 that the contact stresses for spherical (Ball) bearing will always be greater than cylindrical (Roller) bearing at any value of applied force. It is therefore recommended that one should select ball bearing only for low-speed applications otherwise for high speed and larger compressive force roller bearing would perform well.
- It is observed from Fig. 2, 3, 4, 5, 6, 7 & 8 that with the increase in the value of R_1, the contact stress in the ball bearing is constantly decreasing whereas in roller bearing the contact stress remains constant with negligible variations. Hence, it is suggested to keep both the radius same as far as possible in case of a ball bearing to have a better performance while roller bearing remains unaffected with the difference in the radius of the rolling surfaces.
- It is observed from Fig. 9, 10, 11, 12, 13, 14 & 15 that the contact zone for both the cases i.e. ball and roller bearing increases with the increase in radius. However, in any case, the numerical value of the contact zone for roller bearing will be less when compared with ball bearing.
- Hence, it can be concluded that in any condition cylindrical (Roller) bearings are far more effective than spherical (Ball) bearing.

CONCLUSIONS

The Analytical Study of Contact Stress and Contact Zone Analysis of cylindrical (Roller) & Spherical (Ball) Bearings, in Epicycloid Condition Suggest that ball bearings are applicable for low speed applications while roller bearings are applicable for higher speed applications. The study further suggests that the radius of both the surfaces in case of ball bearing should be kept constant for negligible variations in the contact stresses while roller bearing is free from such bindings. Hence at the outset cylindrical (Roller) bearings are far more effective than spherical (Ball) bearing in all working conditions.

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